Workstation III System Evaluation

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Abstract

The Numerical Aerodynamic Simulation Division recently conducted a technology assessment of workstation performance. Five vendor offerings were evaluated based on CPU performance, graphics capability, and cost. Points were assigned as a result of the evaluation. Based on the awarded points, Silicon Graphics Incorporated workstations were found to be the most balanced system. Recommended minimum and ideal configurations are given for SGI, IBM and HP.

1.0 Introduction

One of the technological objectives of the Numerical Aerodynamic Simulation (NAS) program is to provide the advanced computational resources required for the processing of three dimensional aerodynamics, general fluid dynamics, and other large scale scientific simulation and modeling applications. The NPSN (NAS Processing System Network) is an advanced computational facility tailored to the processing of three dimensional aerodynamics, general fluid dynamics, and other large scale scientific simulation and modeling applications. The facility is one of the premier supercomputer centers in the world and provides scientific computational

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services to a wide range of local and remote users from NASA, DOD, other Government agencies, and private industry. Since its inception in 1984, NAS has been interested in high performance graphics workstations. The facility is systematically enhanced by incorporating state of the art high-end graphics workstations for scientific visualization and analysis of supercomputer data results. To maintain this objective, NAS tests and evaluates the latest in high performance computing machinery.

High performance graphics workstations were the target of a recent investigation. NAS conducted a technology assessment of workstation performance including CPU, graphics, and cost. It was determined that the potential workstation vendors under consideration were part of the Scientific Engineering Workstation Procurement (SEWP) that Goddard Space Flight Center awarded in June 1993.

2.0 Method

The evaluation procedure consisted of running a suite of NAS benchmarks on each vendor's machine. The following vendors provided a machine for benchmarking— Digital Equipment Corporation (DEC), Hewlett Packard (HP), International Business Machines (IBM), Silicon Graphics Incorporation (SGI), and Sun Microsystems (Sun). We compiled and ran both a graphics benchmark and a flow solver benchmark on each platform. The results were tabulated and then analyzed based on price and performance. The vital statistics for each machine benchmarked are listed below in table 1.

TABLE 1. Workstation Configurations

Vendor	DEC/Kubota	HP	IBM	SGI	SUN/Evans-Sutherland
Model	Alpha/Denali	735/CRX48Z	580/GTO	Onyx/RE2	10-52/ES 3200
Memory	128 MB	96 MB	384 MB	256 MB	64 MB
OS	Ultrix	HPUX	AIX	IRIX 5.1	Solaris 2.1
Actual Cost	$109,911	$47,998	$107,360	$175,570	$81,561

The Flow Code Benchmark (TFCB) was designed to exercise the working environment of the machine and to measure its floating point performance The benchmark required the machine to successfully compile a series of programs; generate a sequence of grids around a multi-element air foil configuration; run a program which generates interpolation data used to connect the boundaries of these grids and pass information between them; and use these grids and boundary conditions and run the INS2D flow solver for this configuration. The CPU floating point performance was measured using only the execution time of the flow solver.

The INS2D flow solver solves the incompressible Navier-Stokes equations in two-dimensional generalized curvilinear coordinates. It reformulates the equations using the artificial compressibility method to form a hyperbolic system of equations. The convective terms are approximated using an upwind flux-difference splitting scheme. The equations are solved using an implicit Gauss-Seidal line-relaxation method. The finite-difference code accepts structured grids which can have either a single or multiple zones. For connectivity, the zones must have some type of overlap, either pointwise continuous or random. The line-relaxation sweeps are performed sequentially through each zone such that the zonal boundaries are solved implicitly during the sweeping process. The result is a robust and efficient flow solver with fast convergence. The benchmark is single precision and uses about 12 MB of memory.

The graphics benchmark is one executable file which reads a fluid flow data file, draws some images of that data, and prints timings to standard output. The benchmark tests random segments, random triangles, whole and trimmed NURBS, z-buffered wire meshes of width one and two, various polygon meshes, and raster operations such as read, write, and clear. We are mostly interested in these timings, but we are also interested in the appearance of some of the tests. In particular, we frequently need to draw polygonal surfaces overlaid with line segments. This includes such things as polygon outlines, contour lines in scalar fields, and on-the-surface "oilflow" traces (streamlines). This capability is lacking in many present-day systems, and it's presence in the new systems is greatly desired. The graphics benchmark code uses about 34MB of memory.

3.0 Results

The results of both CPU and graphics benchmarks are given below. Figures 1 through 5 highlight the CPU results, as well as the more interesting graphics benchmarks results.

TABLE 2. TFCB Benchmark Results

Vendor	**DEC/Kubota**	**HP**	**IBM**	**SGI**	**SUN/ES**
Model	K3500P2-V620	735 CRX48Z	580 GTO	Onyx-R4400	SS 10-52
Flow (execute time in seconds)	1675	655	1267	1254	1710
MFLOPS	4.9	12.6	6.5	6.6	4.8

TABLE 3. Graphics Benchmark Results

Vendor	DEC/Kubota	HP	IBM	SGI	SUN/ES
Model	K3500P2-V620	735 CRX48Z	580 GTO	Onyx-RE2	SS 10-52
RANDOM SEGMENTS (seg/sec)					
immed big	25806	17582	27586	106667	1905
displ big	35556	23188	30189	320000	*N/A
immed little	25396	26667	31373	100000	2797
displ little	35556	43243	35556	800000	N/A
RANDOM TRIANGLES (tri/sec)					
immed big	3333	1550	649	9357	66
displ big	3200	1652	704	9249	N/A
immed little	20513	18391	16842	69565	1980
displ little	27586	29630	17978	320000	N/A
NURBS (nurbs/sec)					
immed	15	18	10	30	8
displ	148	198	14	30	N/A
immed trim	14	18	19	24	8
displ trim	168	227	2	27	N/A
RASTER OPERATIONS (frames/sec)					
buffer-clear	36	71	0	60	74
image-read	2	1	1	24	0
image-write	5	2	60	20	1
WIREFRAME MESHES (seg/sec)					
immed wd=1	251104	243718	291775	413487	72571
displ wd=1	279947	267304	298073	880328	N/A
immed zbuff wd=1	251104	242293	289735	419849	68118
displ zbuff wd=1	279947	265590	298073	870963	N/A
immed zbuff wd=2	251104	240884	5930	413487	61685
immed zbuff wd=2	279947	265590	5930	870963	N/A
POLYGONAL MESHEs (quads/sec)					
immediate	37607	14666	86802	89027	1498
display	61272	15451	199437	161449	N/A
immed outline	28849	13520	45442	63513	1445
displ outline	43624	14185	63903	131243	N/A
immed contour	18926	11615	23214	64298	968

TABLE 3. Graphics Benchmark Results

Vendor	DEC/Kubota	HP	IBM	SGI	SUN/ES
displ contour	23771	11935	23963	125572	N/A
**immed texture	N/A	14422	N/A	84002	N/A
displ texture	N/A	14543	N/A	142256	N/A

* N/A At the time of the benchmark, display lists were not implemented in the version of NPGL for the Sun with the Evans and Sutherland board.

** texture mapping not available on some platforms.

4.0 Discussion and Analysis

Since NAS ran the benchmarks, the vendor was not allowed to change any lines of either the graphics benchmark code or the flow solver benchmark code. This is not to imply that we thought the codes were already optimized but rather we thought the style of these codes more closely represented a typical NAS user application code. An alternative would have been to run our codes and have the vendor run the codes allowing some percentage of code line change. It should be noted that the graphics benchmark was run on the SGI using native IRIS GL 4.0, the IBM using a port of GL 3.0, and NPGL, which is a beta release of the Portable Graphics Incorporated software, on the DEC/Kubota, SUN/Evans-Sutherland, and HP. NPGL is a third party version of a 3D graphics library fully compatible with the SGI IRIS GL 4.0. Some of the NPGL implementations have not been optimized for each of the hardware platforms.

The graphics benchmark code draws a set of images using GL, a _de_facto_ graphics library standard for three-dimensional interactive computer graphics. Industry-wide benchmarks, with timings provided by the vendors themselves, are not suitable for our needs. This new NAS benchmark code, and the images it produces are more representative of what is typically used within NAS and the aerospace industry. As such, this NAS benchmark should yield numbers which are more closely indicative of actual performance which we may expect to see in our actual production applications. Even if we used the native graphics library on each platform, it is not clear, based on vendor provided numbers, that any of the machines would out perform SGI. As OpenGL is implemented on more hardware platforms, it will replace the need for NPGL and some vendors will try to take full advantage of hardware performance by porting OpenGL to their own platforms.

Although the purpose of this workstation evaluation is to determine which machine will be purchased for the next generation high end graphics workstation, some users require more CPU performance and less graphics. Taking this requirement into account, NAS assigned 60 points for graphics performance and 40 points for CPU performance.

The desired CPU performance on TFCB, based on linpack numbers provided by the vendors, was about 20 MFLOPS. None of the vendors achieved this. Perhaps the numbers could have been closer to 20 MFLOPS if some vendor optimization had been permitted.

The desired graphics performance was 250k, 3D z-buffered Gouraud shaded triangles per second. The benchmark test was for outlined quadrilaterals per second. This is the graphics operation that best typifies a NAS graphics application. The measure of quads/sec is a composite number based on the number of vectors per second and the number of triangles per second. Since a quadrilateral is nothing more than two triangles the performance required on the quads/sec benchmark is roughly 125K quadrilaterals per second.

The price-performance table below shows an analysis of the scores based on the previous paragraphs. The vendor with the best graphics performance was given a score of 60 or normalized, 1. Other vendors scores were normalized based on the vendor achieving the highest score. In addition, the vendor with the best CPU performance was given a score of 40 or 1 and all others were normalized based on that vendor's performance. Two price costs are displayed -- one using the cost based on the vendor provided configuration and another using cost based on the minimum configuration needed to run the benchmarks.

TABLE 4. Price/Performance Evaluation

Vendor Achieved	DEC	HP	IBM	SGI	Sun
quads/sec	43624	14185	63903	131243	1445
MFLOPS	4.9	12.6	6.5	6.6	4.8
Max quads Max MFLOPS		12.6		131243	
Normalized Performance	DEC	HP	IBM	SGI	Sun
quads/sec MFLOPS	.33 .39	.11 1.0	.49 .52	1.0 .52	.02 .38
Weighted Performance	DEC	HP	IBM	SGI	Sun
quads/sec MFLOPS	19.94 15.56	6.48 40.00	29.21 20.63	60.00 20.95	0.66 15.24
Total Points	35.50	46.48	49.85	80.95	15.90
Price Performance	DEC	HP	IBM	SGI	Sun
*Cost - vendor provided configuration	$109,911	$47,998	$107,360	$175,570	$81,561
Total Points	35.50	46.48	49.85	80.95	15.90
$'s/point	$3,098.68	$1,032.59	$2,152.49	$2,168.81	$5,126.20
Cost - est for 64MB	$93,385	$44,910	$56,148	$115,248	$81,561
Total Points	35.50	46.48	49.85	80.95	15.90
$'s/point	$2,630.64	$966.12	$1,126.36	$1,423.65	$5,130.04

* All prices based on SEWP cost

5.0 Recommendations

Below are the recommended minimal and ideal configurations for the three best (based on price/performance) machines in the NAS environment.The prices are from the SEWP contract. The minimal configurations are based on the kinds of jobs currently running on workstations, the size of the root, usr, and tmp file systems, and an optimal amount of swap space. The ideal configuration for the high end workstations would be the same base system configuration but upgraded to have a total of 512 MB of memory and 8 GB of disk space. The cost of a system of this magnitude would be twice the amount budgeted for next generation workstations in the past.

TABLE 5. **HP Minimum Configuration**

Model 755 CRX-48Z Workstation	**$37,349**
includes 128 MB RAM, two 2GB disk, CRX 48Z graphics	
Software - includes Fortran 90, ANSI C, C++, programmer's toolkit	$6,006
FDDI interface	$6,600
Total	**$49,955**

TABLE 6. **IBM Minimum Configuration**

RS/6000 MDL 590 Server / Workstation	**$55,225**
includes 64 MB RAM, 2GB disk, CDROM	
Power GT4XI 24 Bit Graphics adapter	$6,955
2GB SCSI-2 Disk	$3,711
Software - includes Fortran 90, C++, AIX, Graphics Library, ESSL (scientific library)	$11,684
FDDI interface	$5,453
Total	**$83,028**

TABLE 7. **SGI Minimum Configuration**

D-45602-RE Onyx Reality Engine 2	**$109,466**
includes 64 MB RAM, 4MB texture memory, 2GB disk	
2Gb SCSI-2 Disk	$5,802
Software - includes Fortran 77, C++, Documenter's Workbench, NFS, Development option	$4,583
FDDI interface	$6,819
Total	**$126,670**

TABLE 8. **HP Recommended Configuration**

Model 755 CRX-48Z Workstation	**$37,349**
includes 128 MB RAM, two 2GB disk, CRX 48Z graphics	
Software - includes Fortran 90, ANSI C, C++, programmer's toolkit	$6,006
(3) 128 MB memory upgrades (total 512MB)	$28,224
CD-ROM, 4mm DAT Tape	$1,972
4GB additional disks (total 8 Gb) with mini tower	**$7,284**
FDDI Host Interface, dual attach	$6,600
Total	**$87,435**

TABLE 9. **IBM REcommended Configuration**

RS/6000 MDL 590 Server / Workstation	**$55,225**
includes 64 MB RAM, 2GB disk, CDROM	
Power GT4XI 24 Bit Graphics adapter	$6,955
(3) 2 GB SCSI-2 Disk	$11,133
Software - includes Fortran 90, C++, AIX, Graphics Library, ESSL (scientific library)	$11,684
FDDI interface	$5,453
(7) 64 MB Memory upgrade (total 512 MB)	$32,972
8mm Tape	$4,364
Total	**$127,786**

TABLE 10. **SGI Recommended Configuration**

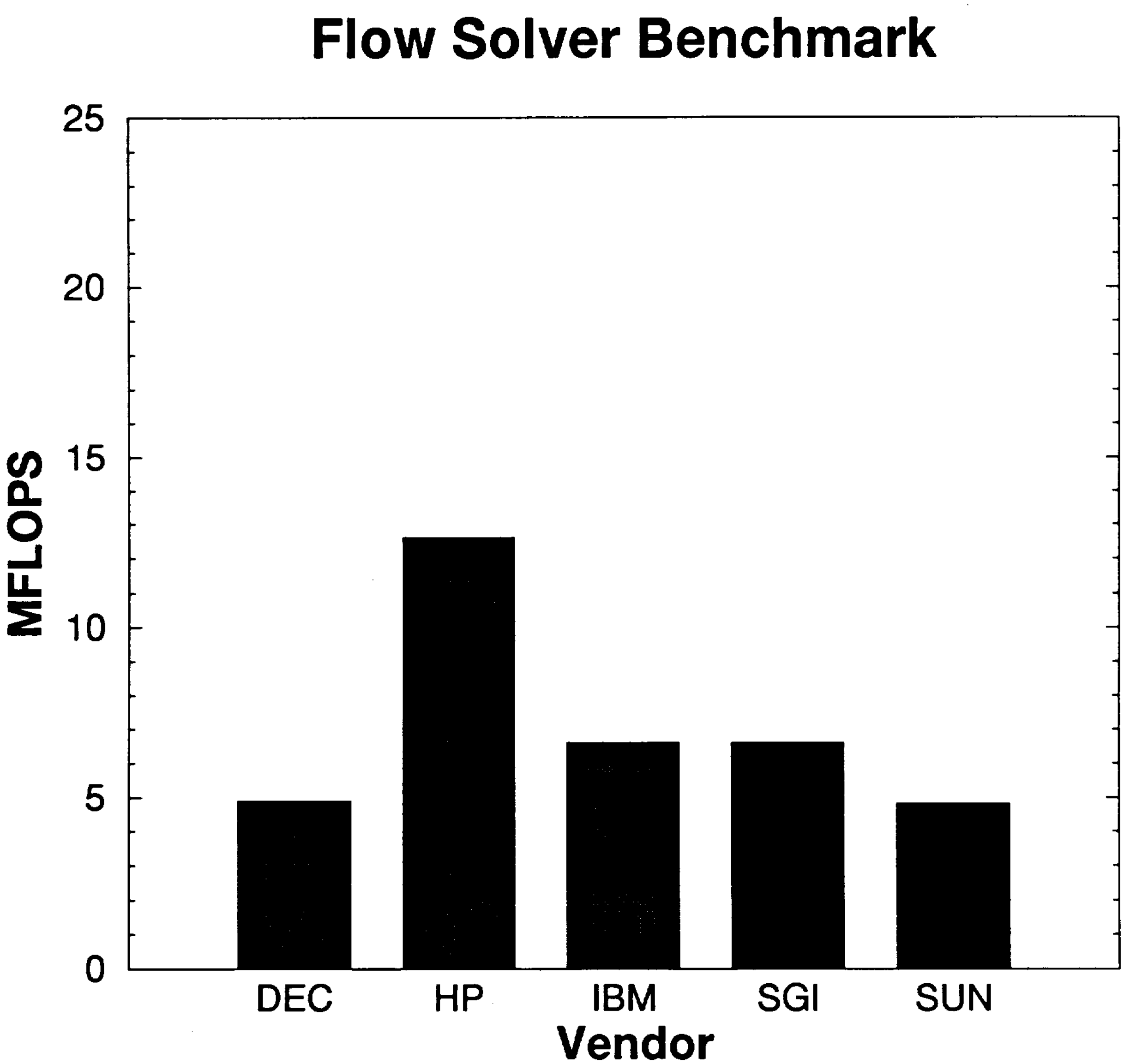
D-45602-RE Onyx Reality Engine 2	**$109,466**
includes 64 MB RAM, 4MB texture memory, 2GB disk	
(3) 2Gb SCSI-2 Disk	$17,406
Software - includes Fortran 77, C++, Documenter's Workbench, NFS, Development option	$4,583
FDDI interface	$6,819
Memory Upgrade (total 512 MB)	$34,000
Total	**$172,274**

6.0 Conclusion

The SGI machine is most balanced system because it gets the most points, as evidenced by figure 6. The line represents a balanced system. Both the distance from the line and position on the line are significant as the best balanced system would be on the line at the top. When cost is factored in, the HP machine represents the lowest dollar per point followed by IBM and SGI as seen in table 4.

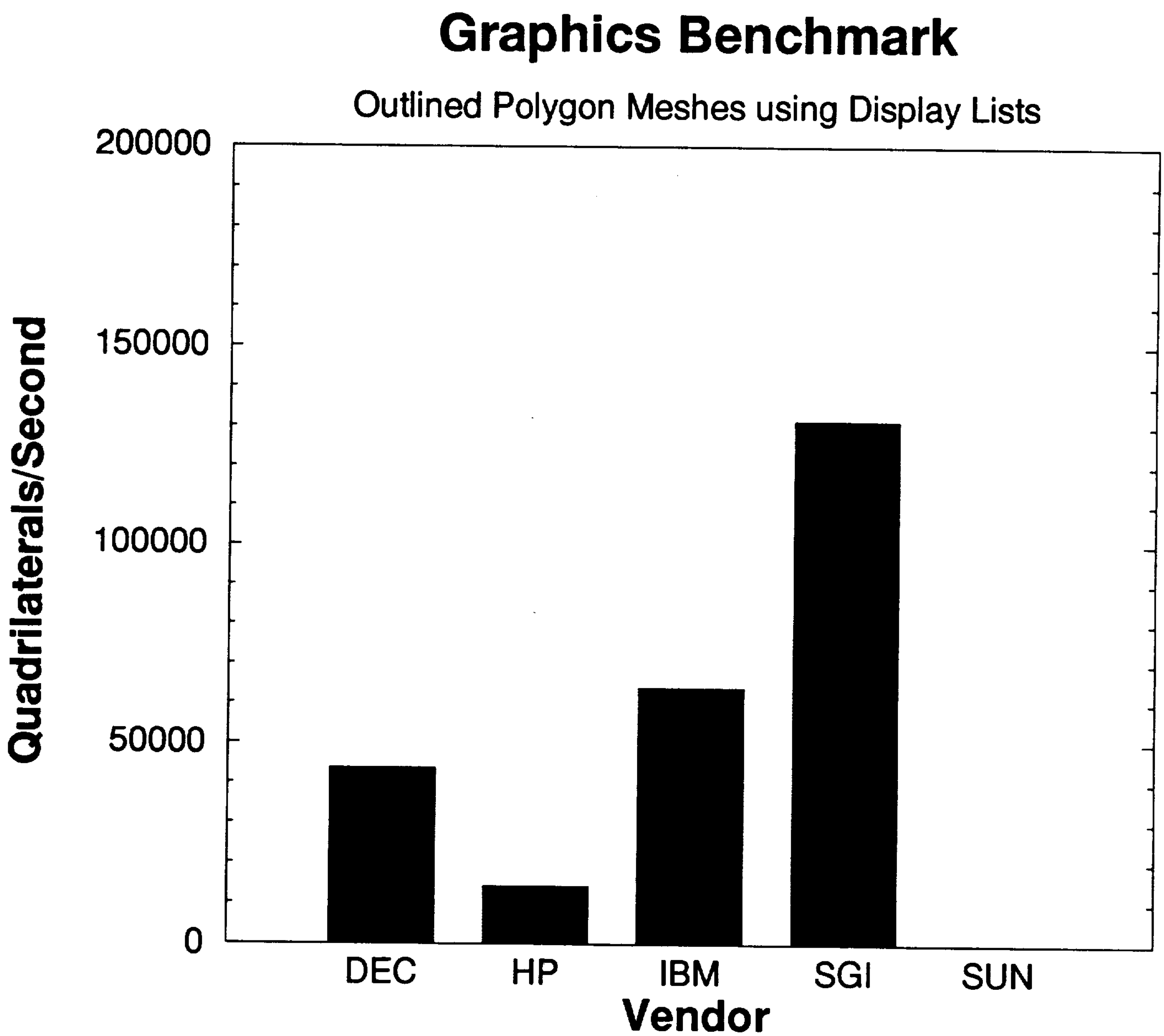
7.0 Acknowledgments

The author wishes to thank Stu Rogers who selected, compiled, and ran the TFCB; Jeff Hultquist, who wrote, compiled and ran the Graphics Benchmark; David Yip, who ran some benchmarks and coordinated with the vendors; and Marisa Chancellor who did the original ground work to start the entire process.



Flow Solver Benchmark
MFLOPS
25
20
15
10
5
0
DEC
HP
IBM
SGI
SUN
Vendor

Figure 1


Graphics Benchmark
Outlined Polygon Meshes using Display Lists
200000
150000
100000
50000
0
Quadrilaterals/Second
DEC
HP
IBM
SGI
SUN
Vendor
Figure 2

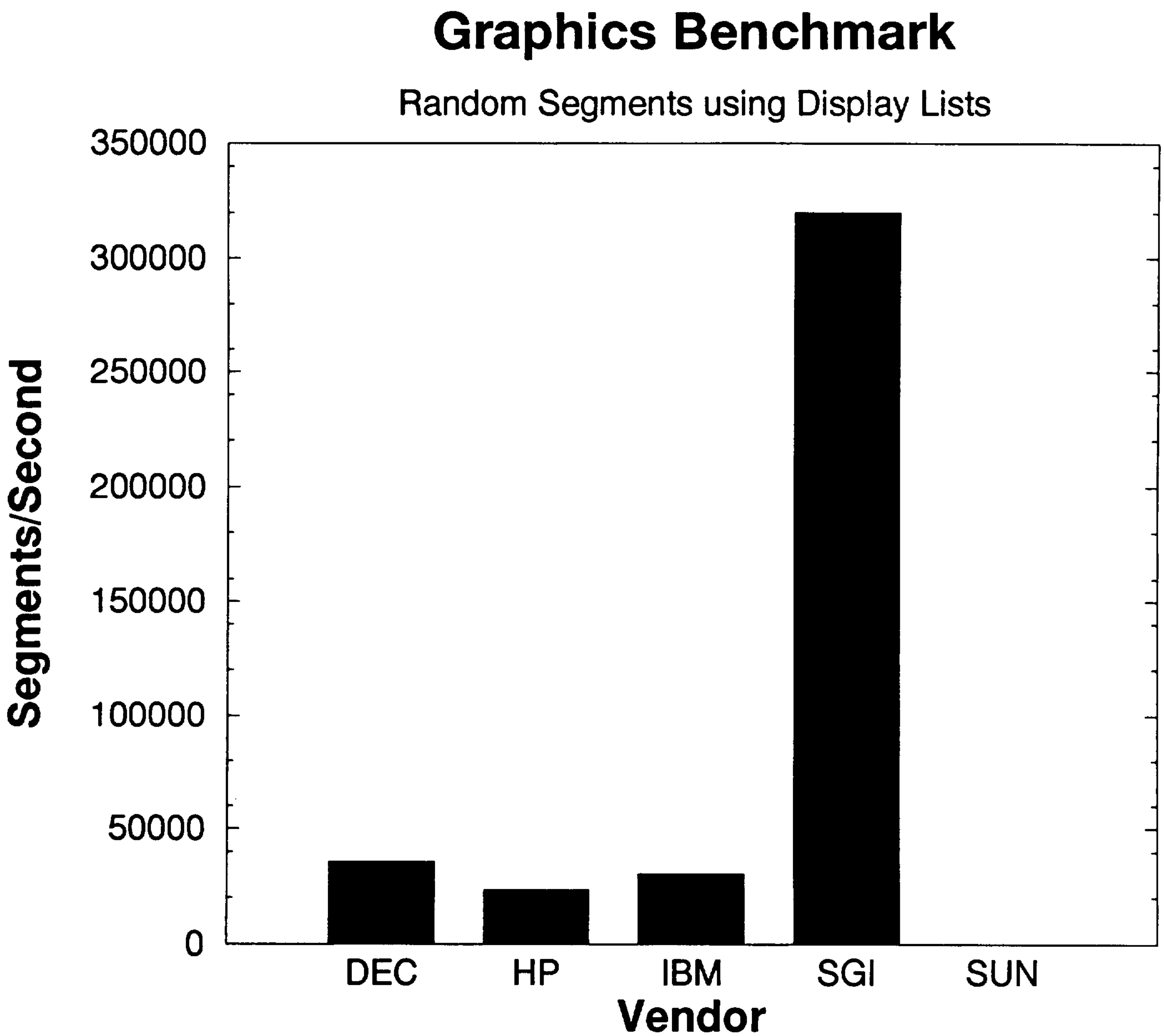

Graphics Benchmark
Random Segments using Display Lists
Segments/Second
350000
300000
250000
200000
150000
100000
50000
0
DEC
HP
IBM
SGI
SUN
Vendor

Figure 3

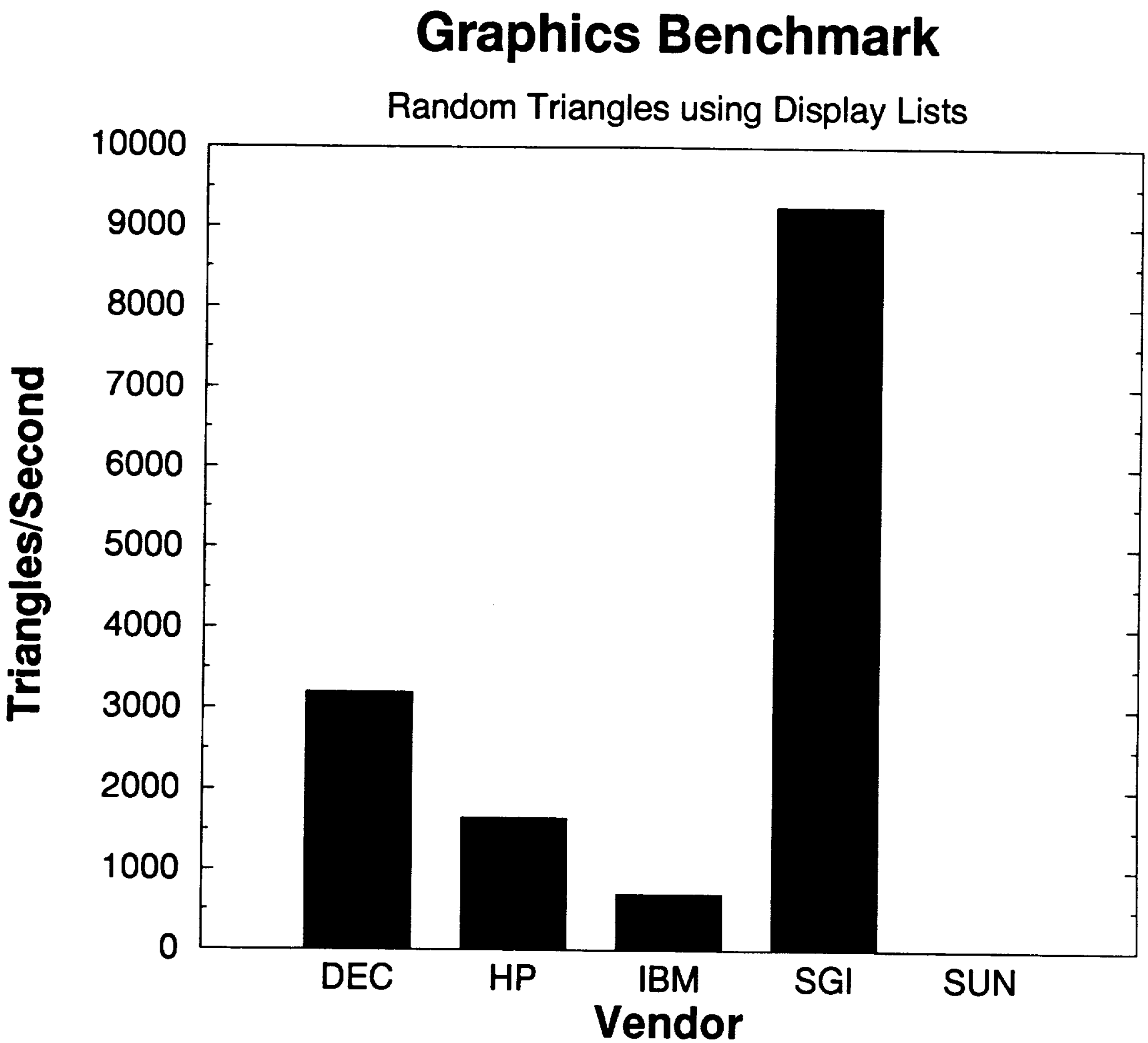

Graphics Benchmark
Random Triangles using Display Lists
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Triangles/Second
DEC
HP
IBM
SGI
SUN
Vendor

Figure 4

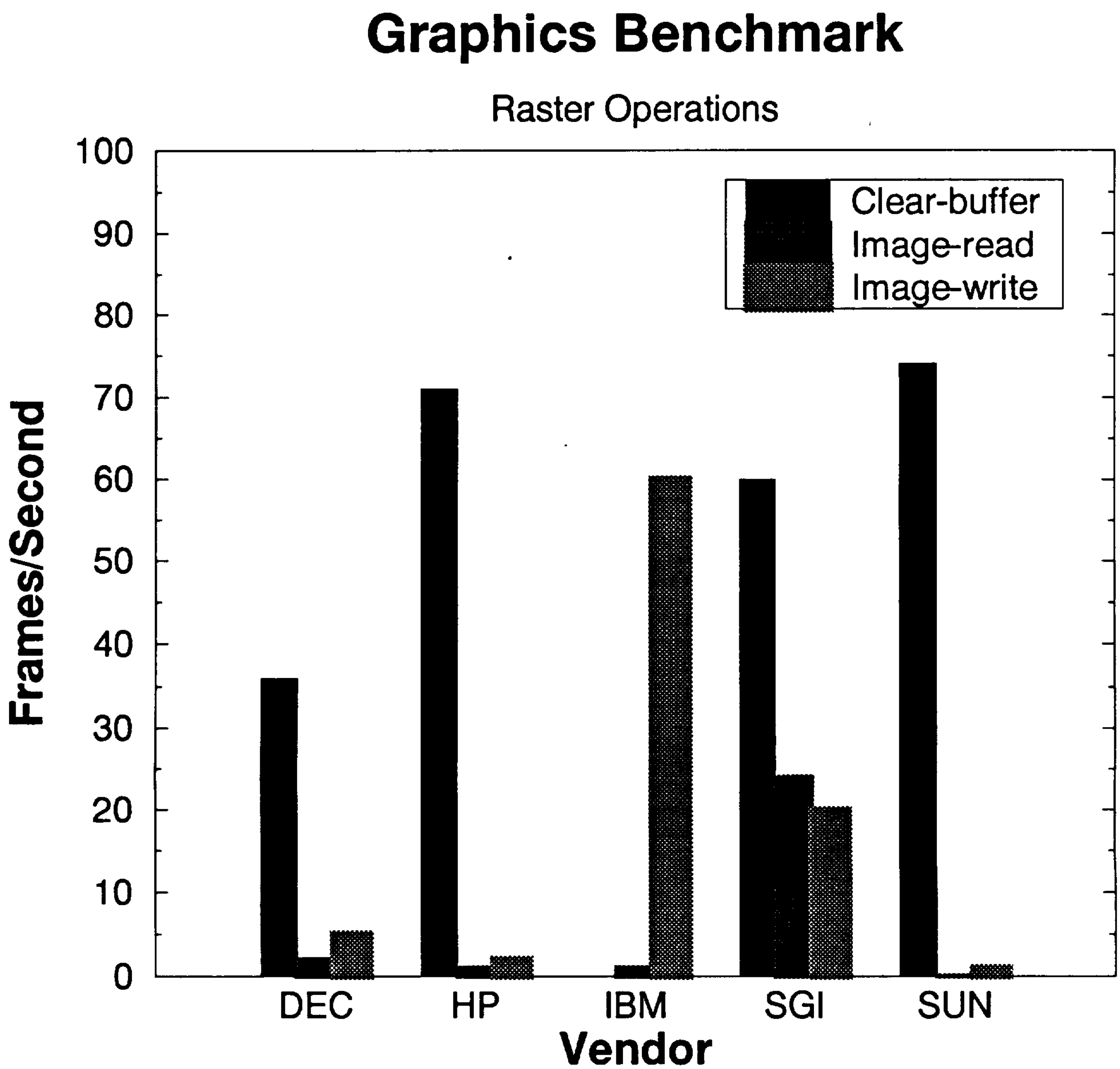

Graphics Benchmark
Raster Operations
Clear-buffer
Image-read
Image-write
Frames/Second
100
90
80
70
60
50
40
30
20
10
0
DEC
HP
IBM
SGI
SUN
Vendor

Figure 5

Performance Analysis

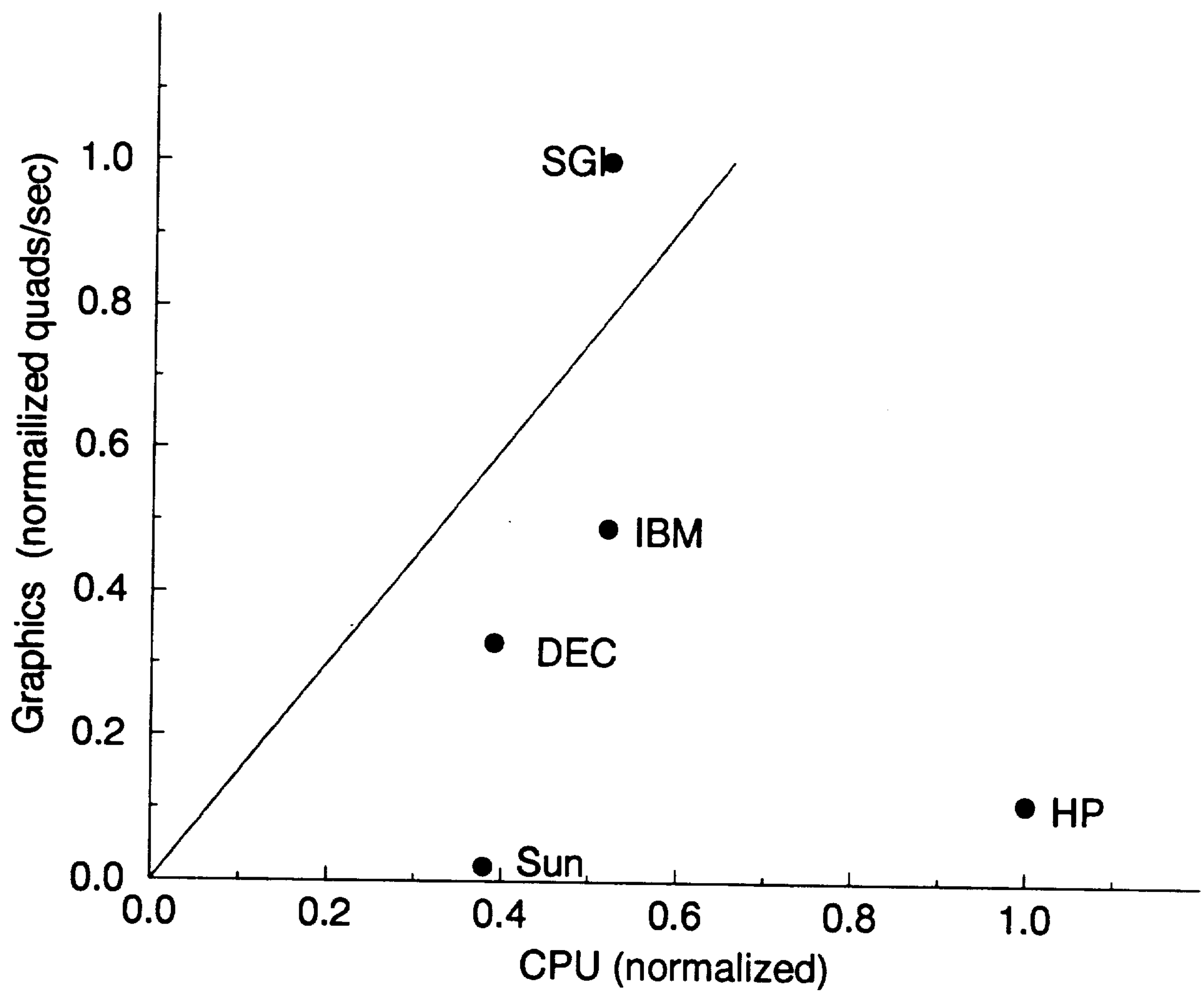


Figure 6

RND TECHNICAL REPORT

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